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# Comparative Evaluation of Porosity in Heat Cure Denture Base Resins Polymerized by Different Methods: An In-Vitro Study

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## Abstract

**Aim:** The purpose of this study was to evaluate the porosity in conventional, microwave and injection moulded heat cured acrylic resins processed by water bath, microwave and injector system respectively using a photographic method and the effect of various factors like materials and thickness of the sample on increasing or decreasing the porosity.

**Material and methods: A t**otal of 60 samples were made; they were divided into three Groups: Group A - Conventional heat cure, polymerized by Water Bath (C), Group B – Microwave cure, polymerized by Microwave Energy (M) and Group C – Injection moulded, polymerized by water bath (I). All the samples were viewed under Optical Microscope. The numbers of pores and area of pores (%porosity) was calculated using the digital image analysis software attached to the microscope and statistically analyzed cured acrylic resin. It was concluded that the Injection moulded Acrylic Resin samples polymerized in a water bath (Group C) exhibited least porosity when compared to Conventionally cured

acrylic resin (Group A) samples and Microwave cured acrylic resin (Group B).

**Keywords**: Injection moulded acrylic resin, Microwave curing

**Introduction**

Conventional acrylic resins have their own shortcomings such as dimensional instability, residual monomer content, porosity, weak strength, water absorption, and colour instability. It can be concluded that though acrylic resin is the most popular and widely used denture base material for over 60 years and it is still not the ideal one[61].

In microwave processing of denture the monomer used is Methylmethacrylate (MMA), which is a polar liquid at room temperature. According to Saunders the advantages of microwave processing of denture base over the conventional processing are reduced curing time, less cumbersome equipment, a cleaner method of processing, shortened dough-forming time, more homogeneous resin dough, and a denture base with superior adaptation to the dental cast[55].

Most of the physical properties of the denture resin cured by injection moulded and microwave energy are proved to be as favourable as those of resin cured by the conventional heat method but the presence of moderate to severe porosity is encountered which is of great concern. The porosity in acrylic resins continues to be one of the undesirable and a complex phenomenon of multifactorial origin. Porosity can severely weaken acrylic resin prosthesis and can also result in high internal stresses and vulnerability of denture base to distortion and warpage[73]. So, maximum efforts should be made to minimise the porosity in the processed dentures.

The present study was planned to evaluate the porosity in conventional, microwave and injection moulded heat cured acrylic resins processed by water bath, microwave and injector system respectively using a photographic method and the effect of various factors like materials and thickness of the sample on increasing or decreasing the porosity.

**Methodology**

The present study was conducted in vitro in the Department of Prosthodontics, Maharaja Ganga Singh Dental College and Research Center, Sriganganagar. Sixty wax samples polymerized by Conventional, Microwave and Injection moulded heat cure reins were selected to study porosity. Two rectangle shaped moulds with 10mm width, 40mm length with varying thickness 3 mm and 6 mm with cover lid was customized. The bottom plate of the metal mold was lubricated with petroleum jelly. Modelling wax was then melted at $65^0C^@$ in steel bowel and poured into the metal molds to obtain 60 wax sample blocks of 10mm x 40mm x 3mm and 6mm thickness (30 each) . The wax sample blocks were divided into 3 study groups which were designated as A, B and C having 20 samples each.

- **Group A -** Conventional heat cure, polymerized by Water Bath **(C)**
- **Group B -** Microwave cure, polymerized by Microwave Energy **(M)**
- **Group C -** Injection moulded cure, polymerized by water bath under constant pressure. **(I)** Each study group was further divided into 2 subgroups with substitutes each comprising of 10 samples of 3 mm and 6 mm thickness (e.g. $C_3$ and $C_6$) respectively as shown in the table below:

**Group A (C)** sample blocks were invested using dental stone matrix in the brass dental flask which was lubricated with petroleum jelly. **Group B** (**M)** sample blocks were invested using dental stone matrix in the Microwaveable flask which was lubricated with petroleum jelly. **Group C (I)** sample blocks were invested in dental stone matrix in

the injection moulded flask which was lubricated with petroleum jelly.

**Group A (C)**:- The brass flask was placed in boiling water for 4 minutes in dewaxing unit to soften the wax. **Group B (M)**:- The microwaveable flask was placed in a microwave oven with a High power setting for 1 minute to soften the wax. **Group C(I) :-** The injection moulded flask placed in water at $90^0$ C for 5 minutes to soften the wax.

**Group A (C) :-** The Heat Cured acrylic resin was mixed in polymer: monomer ratio of 3:1 by volume in acrylic mixing jar . **Group B (M)**:- The microwaveable acrylic resin was mixed in an acrylic mixing jar in the dosage of 9.0 ml of the monomer and 15g of polymer, using a plastic spatula. **Group C(I)** :- The injectable acrylic resin was mixed in capsule in the dosage of 20 ml monomer and 30gm of polymer, using a plastic spatula for 20 seconds.

**Group A (C)**: The flasks were immersed in cold water in an acrylizer and were processed using the polymerization cycle of $74^oC$ for 2 hours followed by 1 hour of terminal boiling at $100^0$ C. **Group B (M)**: The flasks were transferred to the microwave oven and were processed using the polymerization cycle recommended by the manufacturer **Group C(I)** : The flasks were placed in water bath at boiling temperature and processed for 35 minutes under constant pressure of 6 bars.[9]

- The samples were then finished. Each sample was then labeled with lecron's carver to indicate the test groups for identification. Each sample was further cut into 2 cross - sections S1, and S2. The photomicrographs were captured with the camera attached within the optical microscope and were evaluated for the surface porosity with image analysis software.

**Result**

The findings of all the three groups were recorded, tabulated and statistically analyzed using SPSS version 22. Tests performed are Descriptives, Paired T test for intra group comparison, one way ANOVA with post hoc test for inter group comparison.

Table 1: Number of pores according to the groups compared

| Group | Sub - Group | N | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|---|---|
| A (Conventional) | C3 | 10 | 1.00 | 3.00 | 1.7500 | .82496 |
| | C6 | 10 | 1.00 | 2.50 | 1.8000 | .53748 |
| B (Microwave) | M3 | 10 | 1.00 | 2.00 | 1.5500 | .36893 |
| | M6 | 10 | 1.00 | 3.00 | 2.0250 | .58274 |
| C (Injectable) | I3 | 10 | .50 | 1.00 | .8000 | .25820 |
| | I6 | 10 | .50 | 1.00 | .9000 | .21082 |

Graph 1: Number of pores according to the groups compared

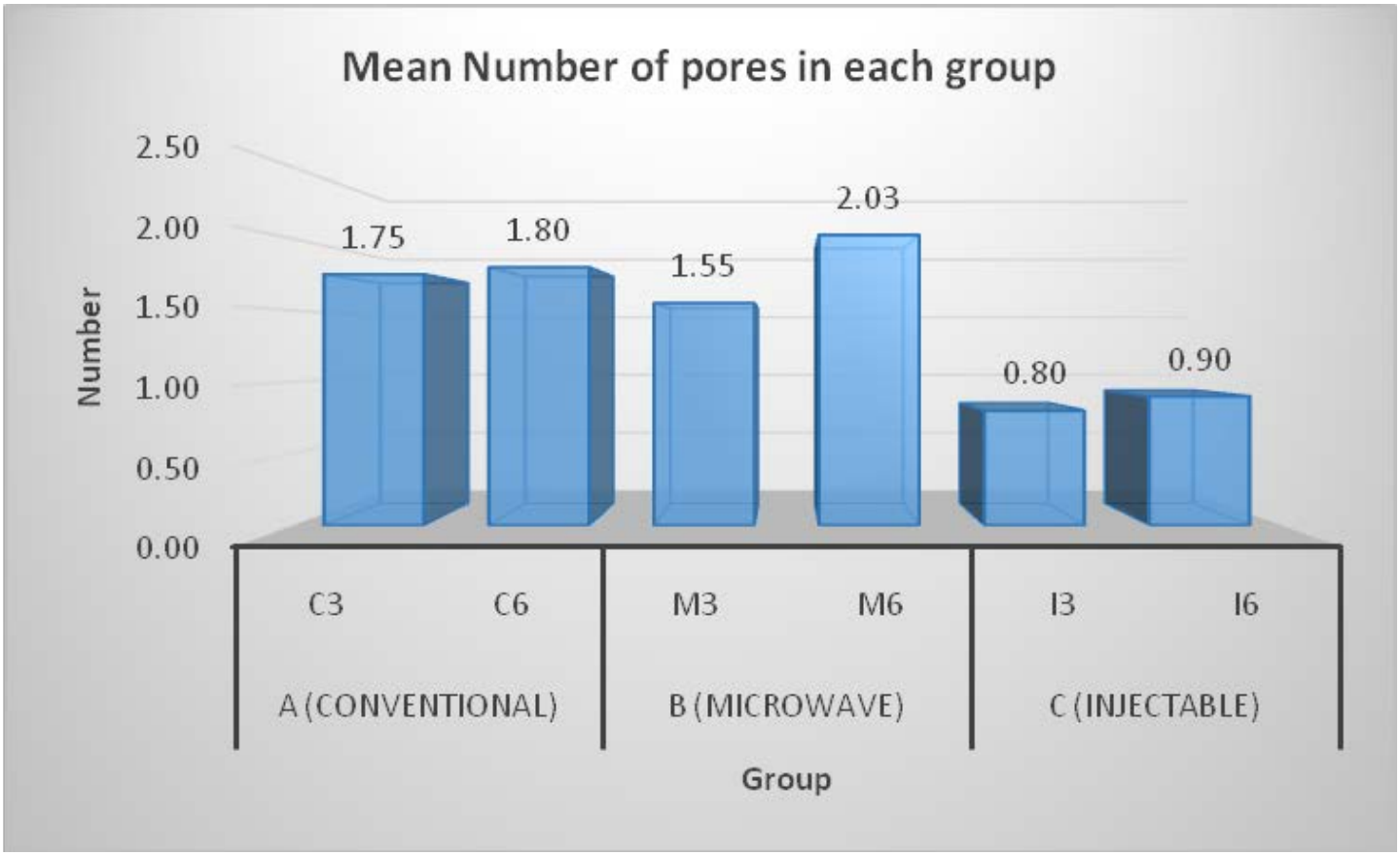


Table 1 and Graph 1 shows distribution of mean and SD values of mean number of pores in Groups A,B and C under study. It can be noted that the mean readings of number of pores in Group A : $C_3$ -1.7500 (SD= 0.8496) & $C_6$ - 1.8000 (SD=0.53784 ), Group B : $M_3$ - 1.5500(SD = 0.36893) & $M_6$ -2.0250 (SD = 0.58274 ) and $I_3$ – 0.8000 (SD = 0.25820) & $I_6$ – 0.9000 (SD = 0.21082).

Table 2: Individual comparison of number of pores in each sub group with each other using Post Hoc Test

| (I) Sub Group | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| C3 | C6 | -.05000 | .22776 | .827 | -.5066 | .4066 |
| | M3 | .20000 | .22776 | .384 | -.2566 | .6566 |
| | M6 | -.27500 | .22776 | .233 | -.7316 | .1816 |
| | I3 | .95000* | .22776 | .000 | .4934 | 1.4066 |
| | I6 | .85000* | .22776 | .000 | .3934 | 1.3066 |
| C6 | C3 | .05000 | .22776 | .827 | -.4066 | .5066 |
| | M3 | .25000 | .22776 | .277 | -.2066 | .7066 |
| | M6 | -.22500 | .22776 | .328 | -.6816 | .2316 |
| | I3 | 1.00000* | .22776 | .000 | .5434 | 1.4566 |
| | I6 | .90000* | .22776 | .000 | .4434 | 1.3566 |

| | | | | | | |
|---|---|---|---|---|---|---|
| M3 | C3 | -.20000 | .22776 | .384 | -.6566 | .2566 |
| | C6 | -.25000 | .22776 | .277 | -.7066 | .2066 |
| | M6 | -.47500* | .22776 | .042 | -.9316 | -.0184 |
| | I3 | .75000* | .22776 | .002 | .2934 | 1.2066 |
| | I6 | .65000* | .22776 | .006 | .1934 | 1.1066 |
| M6 | C3 | .27500 | .22776 | .233 | -.1816 | .7316 |
| | C6 | .22500 | .22776 | .328 | -.2316 | .6816 |
| | M3 | .47500* | .22776 | .042 | .0184 | .9316 |
| | I3 | 1.22500* | .22776 | .000 | .7684 | 1.6816 |
| | I6 | 1.12500* | .22776 | .000 | .6684 | 1.5816 |
| I3 | C3 | -.95000* | .22776 | .000 | -1.4066 | -.4934 |
| | C6 | 1.00000* | .22776 | .000 | -1.4566 | -.5434 |
| | M3 | -.75000* | .22776 | .002 | -1.2066 | -.2934 |
| | M6 | 1.22500* | .22776 | .000 | -1.6816 | -.7684 |
| | I6 | -.10000 | .22776 | .662 | -.5566 | .3566 |
| I6 | C3 | -.85000* | .22776 | .000 | -1.3066 | -.3934 |
| | C6 | -.90000* | .22776 | .000 | -1.3566 | -.4434 |
| | M3 | -.65000* | .22776 | .006 | -1.1066 | -.1934 |
| | M6 | 1.12500* | .22776 | .000 | -1.5816 | -.6684 |
| | I3 | .10000 | .22776 | .662 | -.3566 | .5566 |

*. The mean difference is significant at the 0.05 level.

Table 2 shows p value of number of pores with respect to each subgroup with each other. $C_3$ in comparison to - $C_6$ p value is 0.827, $M_3$ p value is0.384, $M_6$ p value is 0.233 , $I_3$ and $I_6$ p value is 0.000.

**Table 3: Descriptives of number of pores in each group**

| Group | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| A | 20 | 1.00 | 3.00 | 1.78 | 0.68 |
| B | 20 | 1.00 | 3.00 | 1.79 | 0.53 |
| C | 20 | .50 | 1.00 | 0.85 | 0.24 |

Graph 2: Descriptives of number of pores in each group

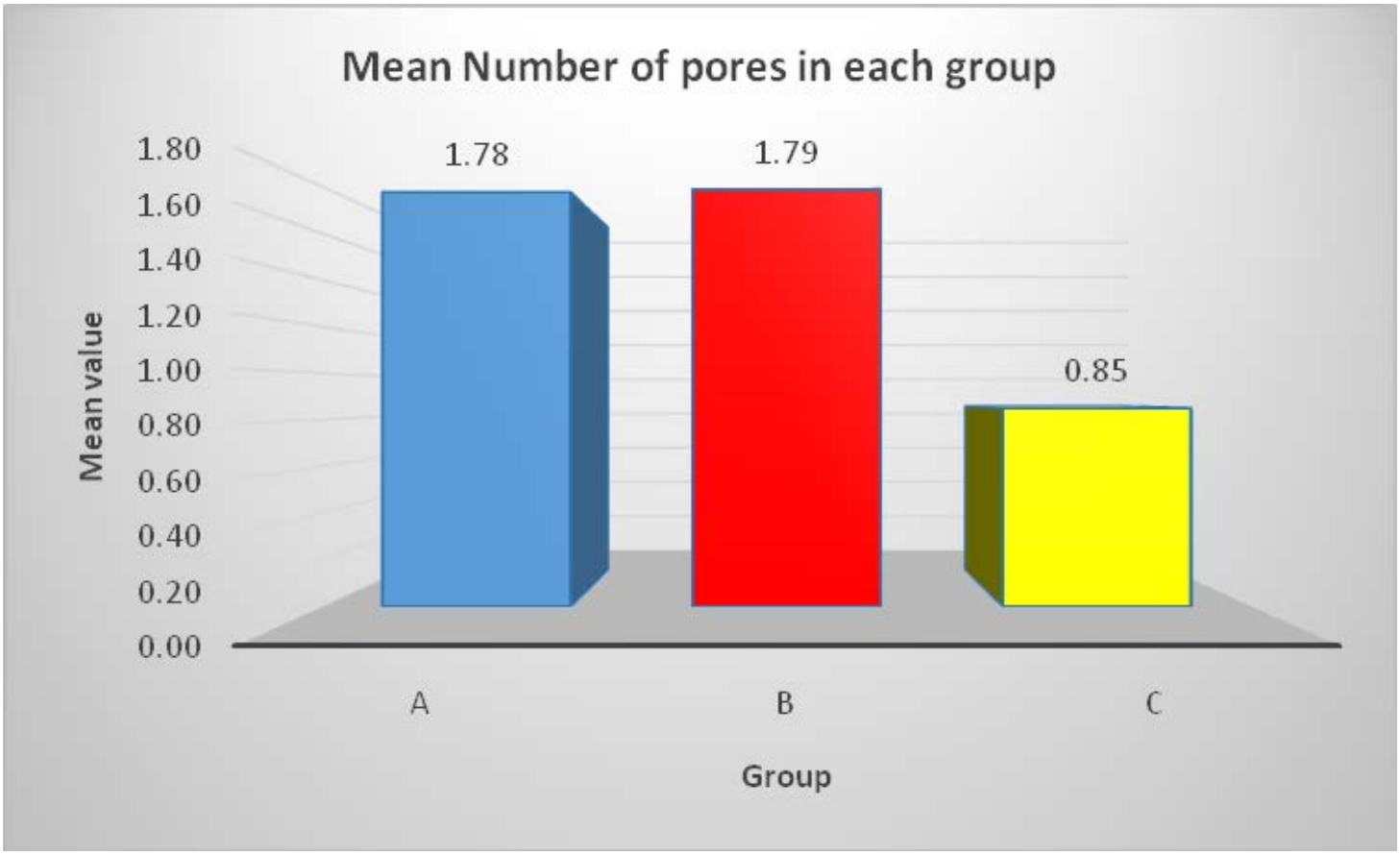


Table 3 and Graph 2 shows distribution of mean and SD values of mean number of pores in Groups A, B and C under study. It can be noted that the mean readings of number of pores in Group A – 1.78(SD =0.68), Group B – 1.79(SD=0.53) and Group C – 0.85(SD=0.24)

Table 4: Individual comparison of number of pores in each group with each other using Post Hoc Test

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| A | B | -.01250 | .16328 | .939 | -.3395 | .3145 |
| | C | .92500* | .16328 | .000 | .5980 | 1.2520 |
| B | A | .01250 | .16328 | .939 | -.3145 | .3395 |
| | C | .93750* | .16328 | .000 | .6105 | 1.2645 |
| C | A | -.92500* | .16328 | .000 | -1.2520 | -.5980 |
| | B | -.93750* | .16328 | .000 | -1.2645 | -.6105 |

*. The mean difference is significant at the 0.05 level.

Graph 3: Individual comparison of number of pores in each group with each other using Post Hoc test

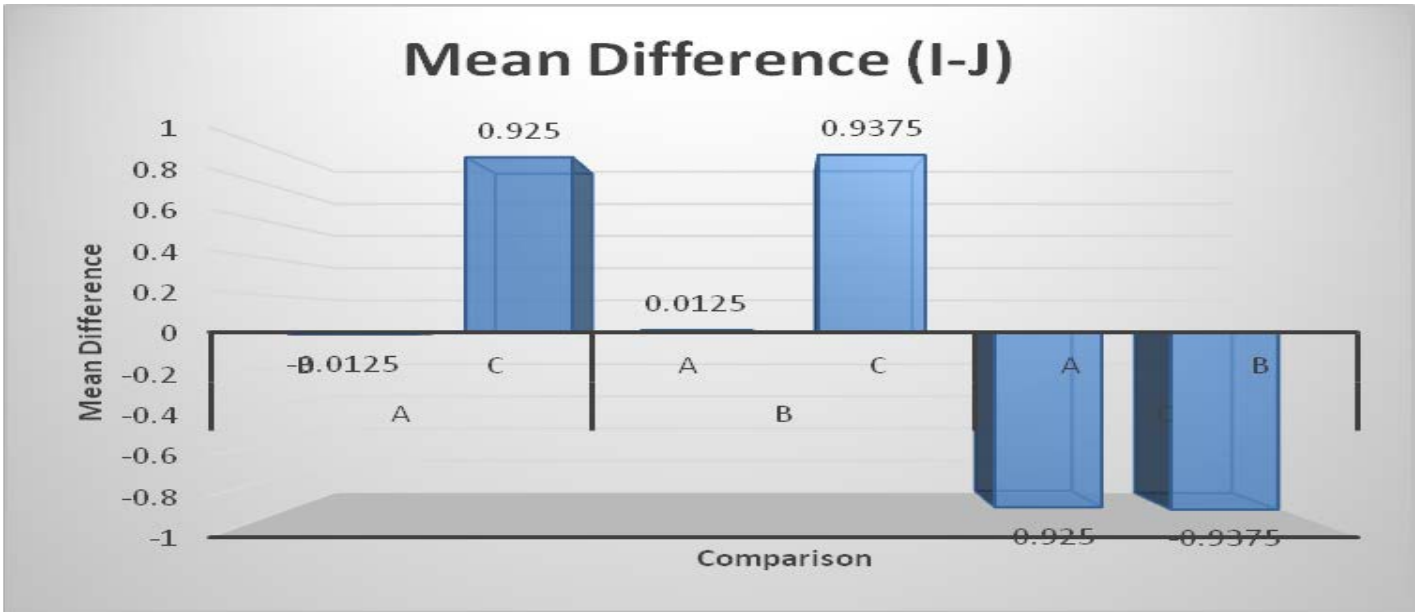


Table 4 and Graph 3 shows mean and p value of number of pores in each group with each other groups. Group A in comparison to Group B p value is0.939 and Group C p value is 0.000.

**Inference: There are statistically highly significant differences present between the various groups compared.**

Table 5: Intra group comparisons (Between Sub Groups) – number of pores

| Group | Sub Group | N | Mean | Std. Deviation | Std. Error Mean | Sig |
|---|---|---|---|---|---|---|
| A | 3 | 10 | 2.0250 | .58274 | .18428 | 0.401 NS |
| | 6 | 10 | 1.7500 | .82496 | .26087 | |
| B | 3 | 10 | 1.8000 | .53748 | .16997 | 0.038* |
| | 6 | 10 | 1.3500 | .33747 | .10672 | |
| C | 3 | 10 | .9000 | .21082 | .06667 | 0.355 NS |
| | 6 | 10 | .8000 | .25820 | .08165 | |

NS – Not significant (P>0.05), * - Statistically Significant (P<0.05)

Graph 4: Intra group comparisons (Between Sub Groups) – number of pores

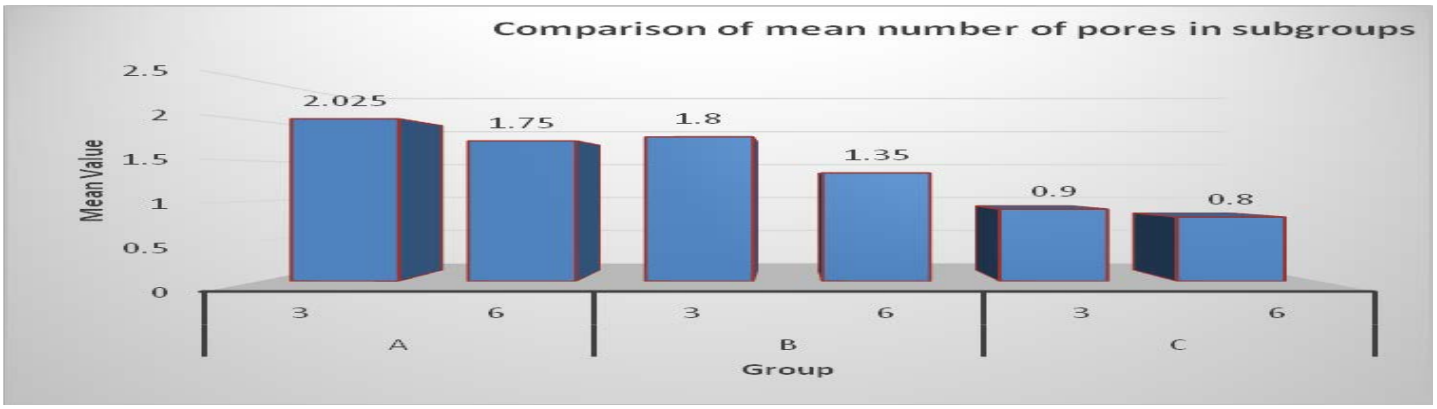

Table 5: Intra group comparisons (Between Sub Groups) – area of pores

Table 5 and Graph 4 shows mean and p value of number of pores in each subgroups 3 and 6mm. Group A p value is 0.401, Group B p value is 0.038 and Group C p value is 0.0.038.

Table 6: Area of pores according to the study groups compared

| Group | Sub - Group | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|---|
| A (Conventional) | C3 | 10 | .037 | .398 | .134 | .103 |
| | C6 | 10 | .025 | .907 | .292 | .236 |
| B (Microwave) | M3 | 10 | .037 | .244 | .158 | .080 |
| | M6 | 10 | .133 | 1.367 | .423 | .431 |
| C (Injectable) | I3 | 10 | .038 | .133 | .095 | .030 |
| | I6 | 10 | .023 | .103 | .047 | .032 |

Graph 5 :Area of pores according to the study groups compared

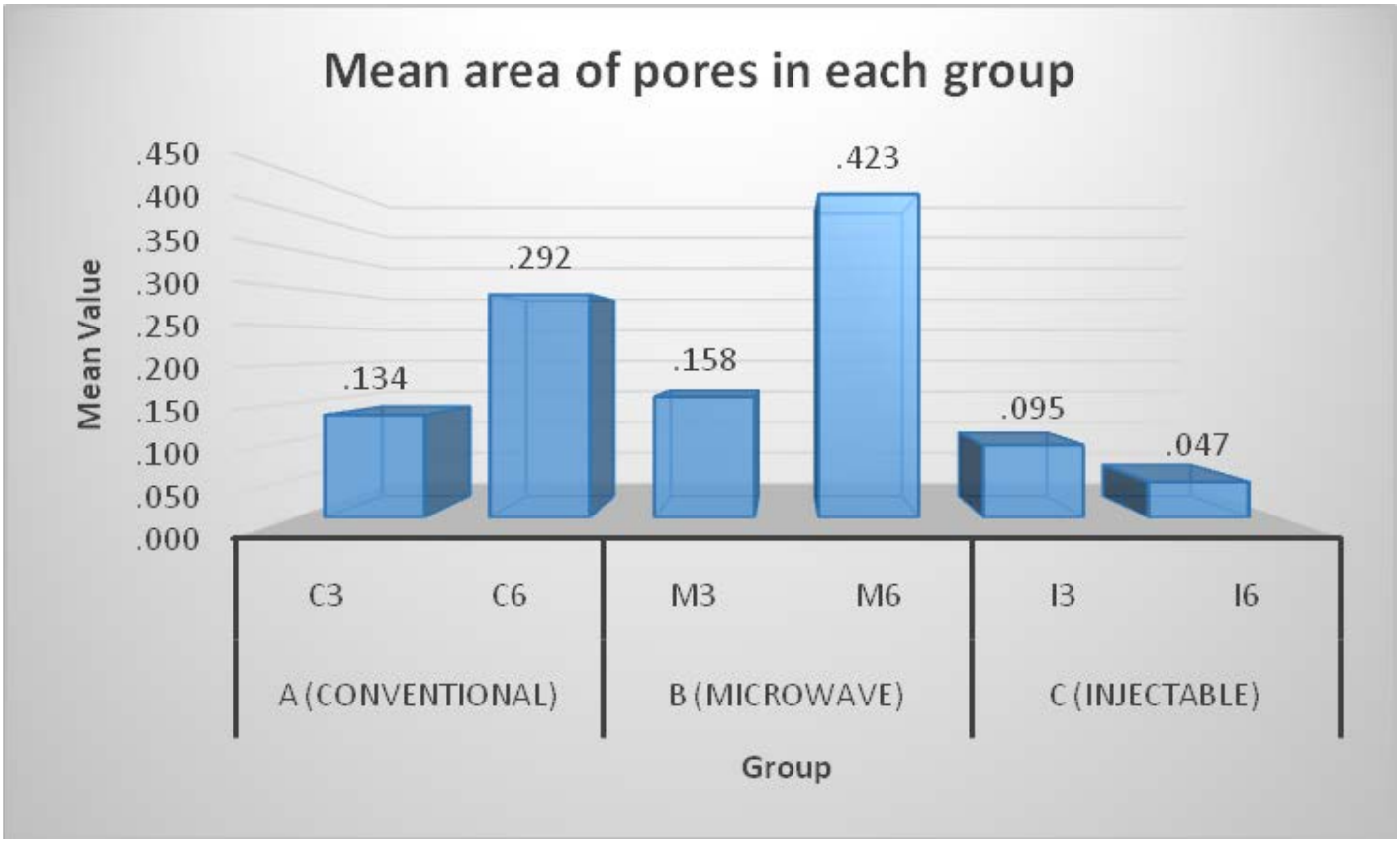


Table 6 and Graph 5 shows distribution of mean and SD values of mean area of pores in Groups A,B and C under study. It can be noted that the mean readings of area of pores in Group A : $C_3$ -0.134 (SD= 0.103) & $C_6$ – 0.292 (SD=0.236 ), Group B : $M_3$ – 0.158(SD = 0.080) & $M_6$ - 0.423 (SD = 0.431 ) and $I_3$ – 0.95 (SD = 0.030) & $I_6$ – 0.047 (SD = 0.032).

Table 7: Individual comparison of Area of pores in each sub group with each other using Post Hoc Test

| (I) SubGroup | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| C3 | C6 | -.157300 | .093172 | .097 | -.34410 | .02950 |
| | M3 | -.023950 | .093172 | .798 | -.21075 | .16285 |
| | M6 | .28855 | .093172 | .003 | -.47535 | -.10175 |
| | I3 | .039750 | .093172 | .671 | -.14705 | .22655 |
| | I6 | .087500 | .093172 | .352 | -.09930 | .27430 |
| C6 | C3 | .157300 | .093172 | .097 | -.02950 | .34410 |
| | M3 | .133350 | .093172 | .158 | -.05345 | .32015 |
| | M6 | -.131250 | .093172 | .165 | -.31805 | .05555 |
| | I3 | .197050* | .093172 | .039 | .01025 | .38385 |
| | I6 | .244800* | .093172 | .011 | .05800 | .43160 |
| M3 | C3 | .023950 | .093172 | .798 | -.16285 | .21075 |
| | C6 | -.133350 | .093172 | .158 | -.32015 | .05345 |
| | M6 | -.264600* | .093172 | .006 | -.45140 | -.07780 |
| | I3 | .063700 | .093172 | .497 | -.12310 | .25050 |
| | I6 | .111450 | .093172 | .237 | -.07535 | .29825 |
| M6 | C3 | .288550* | .093172 | .003 | .10175 | .47535 |
| | C6 | .131250 | .093172 | .165 | -.05555 | .31805 |
| | M3 | .264600* | .093172 | .006 | .07780 | .45140 |
| | I3 | .328300* | .093172 | .001 | .14150 | .51510 |
| | I6 | .376050* | .093172 | .000 | .18925 | .56285 |
| I3 | C3 | -.039750 | .093172 | .671 | -.22655 | .14705 |
| | C6 | -.197050* | .093172 | .039 | -.38385 | -.01025 |
| | M3 | -.063700 | .093172 | .497 | -.25050 | .12310 |
| | M6 | -.328300* | .093172 | .001 | -.51510 | -.14150 |
| | I6 | .047750 | .093172 | .610 | -.13905 | .23455 |
| I6 | C3 | -.087500 | .093172 | .352 | -.27430 | .09930 |
| | C6 | -.244800* | .093172 | .011 | -.43160 | -.05800 |
| | M3 | -.111450 | .093172 | .237 | -.29825 | .07535 |
| | M6 | -.376050* | .093172 | .000 | -.56285 | -.18925 |
| | I3 | -.047750 | .093172 | .610 | -.23455 | .13905 |

*. The mean difference is significant at the 0.05 level.

Table 7 shows p value of area of pores with respect to each subgroup with each other. $C_3$ in comparison to - $C_6$ p value is 0.97, $M_3$ p value is0.798, $M_6$ p value is 0.003 , $I_3$ p value is 0.671 and $I_6$ p value is 0.352.

Table 8 : Descriptives of Area of pores in each group

| Group | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| A | 20 | .025 | .907 | .213 | .195 |
| B | 20 | .037 | 1.367 | .291 | .331 |
| C | 20 | 0.023 | 0.133 | .071 | .039 |

Graph 6: Descriptives of Area of pores in each group

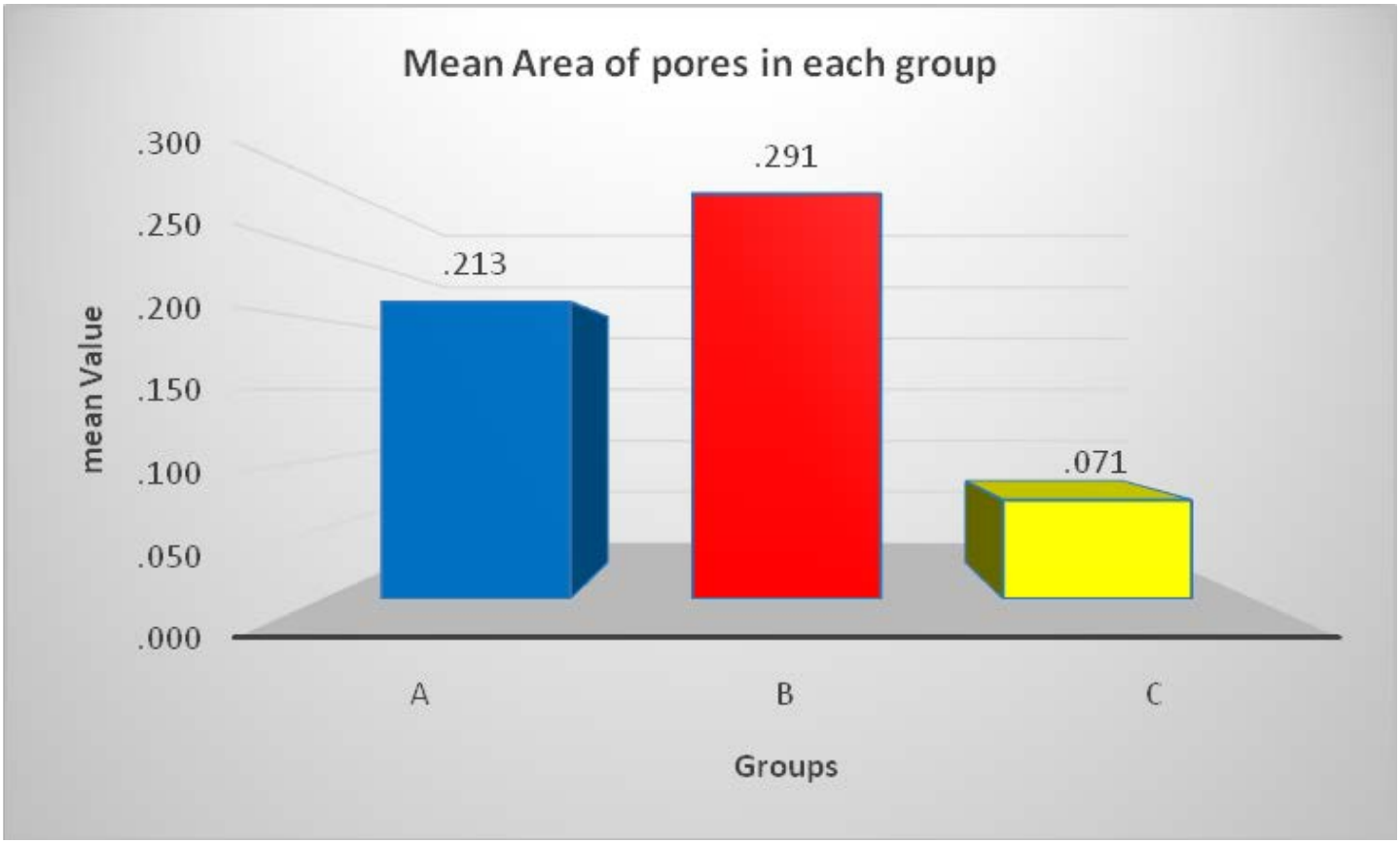


Table 8 and Graph 6 shows distribution of mean and SD values of mean area of pores in Groups A,B and C under study. It can be noted that the mean readings of number of pores in Group A – 0.213(SD =0.195), Group B – 0.291(SD=0.331) and Group C – 0.071(SD=0.039).

Table 9: Individual comparison of area of pores in each group with each other using Post Hoc Test

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| A | B | -.077600 | .070450 | .275 | -.21867 | .06347 |
| | C | .142275* | .070450 | .048 | .00120 | .28335 |
| B | A | .077600 | .070450 | .275 | -.06347 | .21867 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | C | .219875* | .070450 | .003 | .07880 | .36095 |
| C | A | -.142275* | .070450 | .048 | -.28335 | -.00120 |
| | B | -.219875* | .070450 | .003 | -.36095 | -.07880 |
| *. The mean difference is significant at the 0.05 level. | | | | | | |

NS – Not significant (P>0.05), * - Statistically Significant

(P<0.05)

Graph 7: Individual comparison of area of pores in each group with each other using Post Hoc Test.

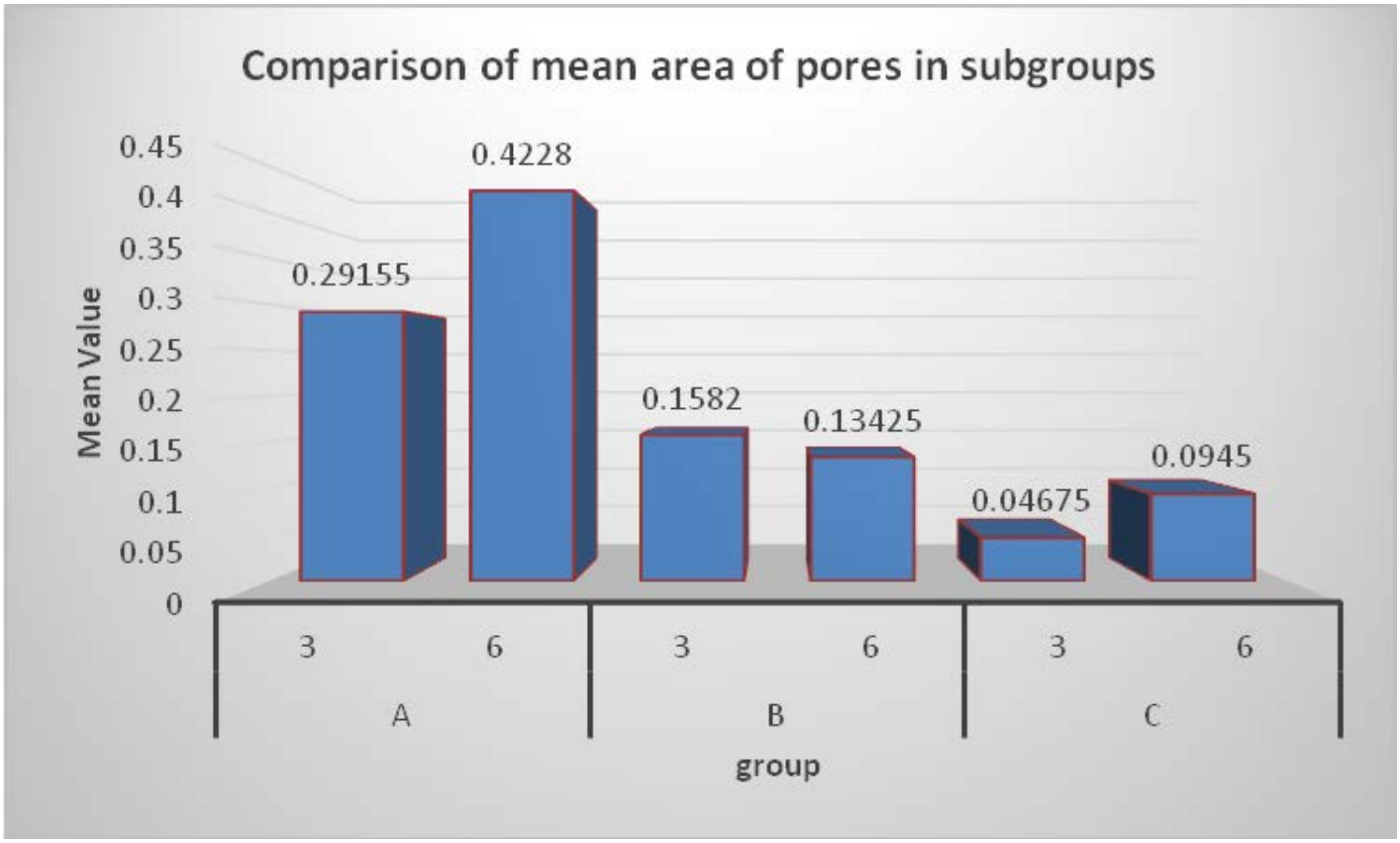


Table 9 and Graph 7 shows mean and p value of area of pores in each group with each other groups. Group A in comparison to Group B p value is0.275 and Group C p value is 0.048. Group B in comparison to Group C 0.003.

**Inference:**There are statistically highly significant differences present between the various groups compared. It is observed that number and area of pores $I_3<I_6<C_3<M_3<C_6<M_6$

**Discussion**

The most popular denture base acrylic resin in use is heat cured poly (methyl-methacrylate) (PMMA). Virtually all complete dentures are constructed from this material using the conventional polymer/monomer dough moulding technique and cured using a water bath system. Heat curing, chemical curing by pouring technique, light curing , microwave curing and injection moulded curing by pressure/heat resin have been extensively studied for denture base processing.

In previous studies, conducted by **Phillip W Wallace[70], L..Smith[56], C.P. Lai[38]** most of the physical properties such as dimensional accuracy, Transverse strength , Modulus of Elasticity, Izod Impact Strength, hardness, flexural strength, solubility of denture base resins polymerized with microwave energy and conventional

method were comparable. **Yunus N** [70] found that among the denture processing methods , injection moulding has always been interesting for researchers because of compensation of polymerization shrinkage due to pressure exerted by injection of the acrylic resin. Injection moulded technique was introduced by **Pryor in 1942**[47].In **1970, Ivoclar** (Schaan, Liechtenstein) introduced an injection-molding system that used an acrylic resin modified for the injection-molding process [24]. Acrylic dentures using injection moulding of acrylic resin reduce traumatic, toxic and allergic complications. Patients' comfort is guaranteed by the precise fit of the acrylic dentures as well as minimum level of residual monomer and easy maintenance[25].

So in this study Injection moulded heat cure resins was used as one of the best methods to put into use with improved all the physical properties. Microwave cured was used as one of the methods to put into use all the advantages of microwave processing. Also conventional heat cured acrylic resin was cured by conventional water bath method as it is one of the most common method of curing which is being used since many years in the field of dentistry.

**Conclusion**

Microwave cured acrylic resin (Group B) samples exhibited insignificant increase in porosity when compared to Conventionally cured acrylic resin (Group A) samples. Injection moulded Acrylic Resin samples polymerized in a water bath (Group C) exhibited least porosity when compared to Conventionally cured acrylic resin(Group A) samples and Microwave cured acrylic resin (Group B). There was no significant increase in porosity on increasing the thickness in Conventional (Group A), Microwave processed (Group B) and Injection moulded (Group C) acrylic resin samples. Microwave cured acrylic resin samples (Group B) exhibited insignificant increase in number and area of pores when compared to Conventionally cured acrylic resin samples (Group A). Therefore, it is suggested that Injection moulded acrylic resin considered better material as compare to Microwave cured acrylic resin and Conventionally cured acrylic resin.

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